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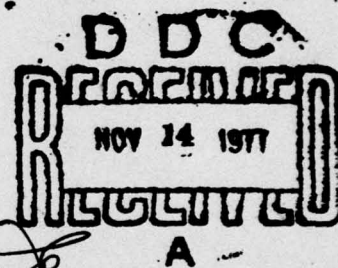
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**EVALUATION OF AN IMPULSE TESTING  
TECHNIQUE FOR NONDESTRUCTIVE  
TESTING OF PAVEMENTS**

**ERIC H. WANG CIVIL ENGINEERING RESEARCH FACILITY  
UNIVERSITY OF NEW MEXICO  
BOX 25, UNIVERSITY STATION  
ALBUQUERQUE, NEW MEXICO 87131**

**SEPTEMBER 1977**

**FINAL REPORT FOR PERIOD  
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| 20. ABSTRACT (Continue on reverse side if necessary and identify by block number)<br>This report documents the results of a study concerned with the evaluation of a proposed technique to perform nondestructive load evaluations of airfield pavements. This technique consists of determining the speed of propagation of the phase velocities through the various layers of a pavement system. A research plan to further develop the technique is also recommended. This plan contains statements of work, equipment recommendations, a proposed budget, and a schedule. |   |  |

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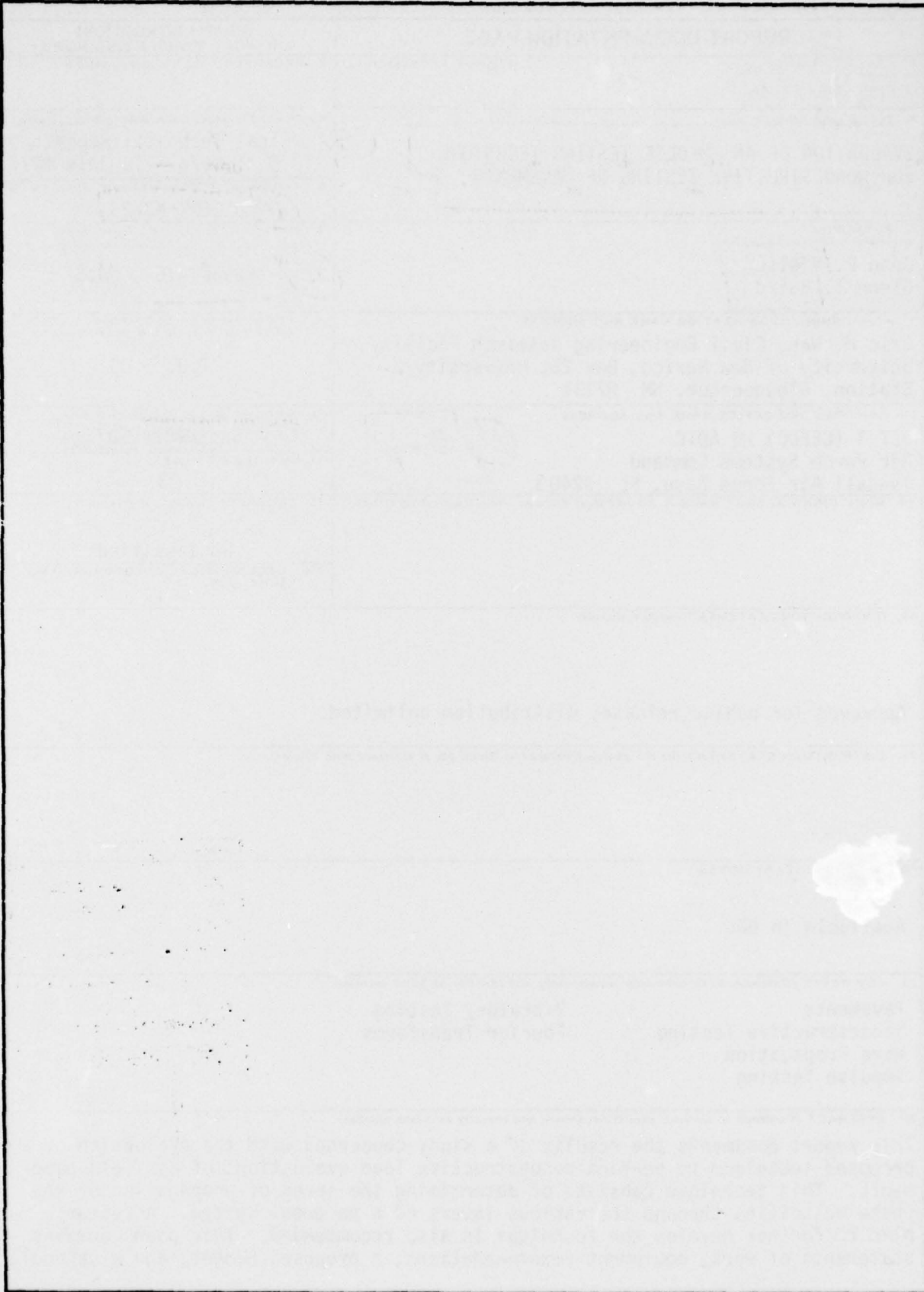
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# PREFACE

This report documents work performed during the period 18 October 1976 through 18 July 1977 by the University of New Mexico under contract F29601-76-C-0015 with the Air Force Civil Engineering Center (AFCEC). On 8 April 1977, AFCEC was reorganized into two organizations. AFCEC became part of the Air Force Engineering and Services Agency. The R&D function remains under Air Force Systems Command as Det 1 (Civil and Environmental Engineering Development Office - CEEDO) HQ ADTC. Both units remain at Tyndall AFB FL 32403. This technical effort was completed under the auspices of CEEDO. Mr L. M. Womack was program manager for AFCEC and CEEDO.

This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

*L. M. Womack*  
L. M. WOMACK  
Chief, A/C Operational Surfaces Division  
*G. P. York*  
GUY P. YORK, Lt Col, USAF  
Director of Civil Engineering Research

*Joseph S. Pizzuto*  
JOSEPH S. PIZZUTO, Col, USAF, BSC  
Commander

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## SECTION I INTRODUCTION

### BACKGROUND

The Civil Engineering Research Facility (CERF) has designed and constructed a test van which is used to perform nondestructive pavement testing (NDPT) on airfield pavements. A large vibrator is used to induce Rayleigh and shear waves into the pavement. (Compressional waves are also generated; however, data from these waves are not used in the analysis.) The equipment, the technology to reduce the data, and the computer codes required to predict the service life (gross aircraft loads and permitted coverages) of a pavement have been transferred to the Air Force Civil Engineering Center (AFCEC). AFCEC now routinely uses the nondestructive load evaluation technique developed by CERF in its pavement evaluation program.

### OBJECTIVE

To better meet the operational needs of the Air Force, a requirement developed for an air-transportable NDPT device. Accordingly, CERF was directed to perform a concept study (Reference 1) to suggest an equipment package which would reduce the size of the pavement tester so as to make it air-transportable in a C-130 aircraft. This report summarizes that work and recommends further development of a prototype air-transportable NDPT device.

### Reference

1. Nielsen, John P., *Feasibility Study for an Air-Portable, Nondestructive Pavement Testing Device*, Letter Report AP-21, Civil Engineering Research Facility, University of New Mexico, Albuquerque, New Mexico, June 1976.



## SCOPE

The scope of the work reported herein includes the results of the following tasks:

- (1) A review of candidate impulse-type pavement loaders and construction of a first-generation loader (Section II).
- (2) Tests to establish accelerometers which are compatible with impulse-type testing (Section III).
- (3) Field tests on a wide variety of pavements with the impulse loader and comparison of the phase angle/frequency plots obtained from impulse testing and those obtained from vibratory testing (Section IV).
- (4) Preparation of a plan to build and evaluate an air-portable impulse device. Included in this plan are equipment requirements, a budget, and a schedule for final development of the device and its support systems (Section V).

## SECTION II

### IMPULSE LOADER

NDPT is a classic system identification problem. By applying known loads to a pavement, measuring the resulting response, and making assumptions about the system, it is possible to estimate or identify system parameters such as elastic moduli. In principle this is no different from applying known inputs to an accelerometer, measuring the response, making assumptions about the appropriate system model, and estimating or identifying such parameters as natural frequency or damping.

In the past, NDPT was performed almost exclusively with surface vibrators, which apply a sinusoidal force to the surface of the pavement. The reasons for selecting a sinusoidal load over other reasonable inputs are not known. However, it is possible to speculate on a few obvious reasons: First, early developments in NDPT occurred at a time when field system identification was in its infancy (Reference 2) and very little was known about system identification for input/output pairs other than sinusoids. Second, mechanical, hydraulic, and electromechanical vibrators were well developed and readily available when NDPT started (circa 1950); thus, little or no development effort was required to obtain a reasonable loading device. Early vibrators were small and light and as the need for heavier vibrators developed, sinusoidal systems naturally followed the earlier approach; i.e., technology focused on vibrating larger masses, not on the nature of the forcing function. And third, the early work on NDPT with sinusoidal loading produced promising results, and thus there was never significant motivation to use other than sinusoidal loads.

Whatever the reasons, surface vibrators have dominated the NDPT field, and they have become increasingly more complex, sophisticated, reliable, and accepted. The state-of-the-art is probably best characterized by the CERF NDPT Van (Figure 1). The van is divided into three compartments. The forward compartment contains a 100-kW diesel generator, which supplies all the electrical energy for the van. The central compartment contains the  $\pm 5000$ -lbf

#### Reference

2. Nijboer, I. W., "Investigation Into the Dynamic Properties of Road Construction," *Science and Industry*, Vol. 2, No. 5, 1955.

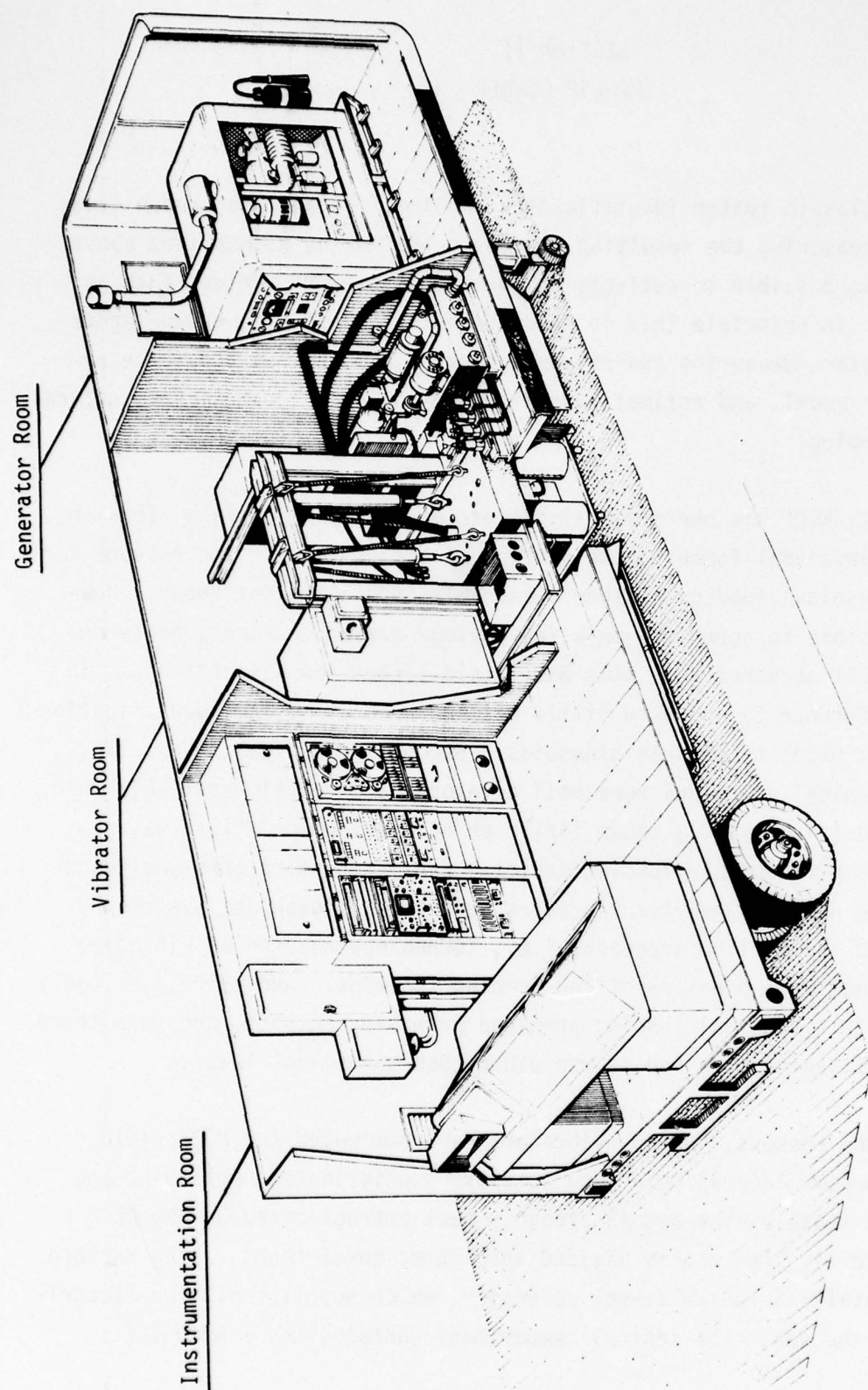


Figure 1. CERF Nondestructive Pavement Test Van



electromagnetic vibrator, the oil cooling system for the vibrator, the power supply for the field coil, and the hydraulic system for raising and lowering the vibrator. The instrumentation section is designed for maximum flexibility so that the van can be used to perform several types of pavement tests (Reference 3).

The CERF NDPT Van also illustrates the principal disadvantage of surface vibrators. An examination of the van reveals that most of the equipment costs and much of the weight and space of the van are allocated to the vibrator and its support equipment; the instrumentation required for the basic objective of system identification occupies comparatively little space. This imbalance between the mechanical loading equipment and the rest of the system results in a total system which is large and not air-transportable. AFCEC pavement evaluation teams are air-mobile and they employ equipment packages which are transported in a C-130 aircraft. Pavement load evaluation, i.e., NDPT, is an integral part of the evaluation process and, hence, the equipment must be air-transportable.

At the time the CERF NDPT Van was developed (circa 1969), vibrator technology dictated the size of the van; viz., sufficiently large enough to support the vibrator and its support equipment. Since that time the field of system identification based on transient behavior has grown explosively. In addition, reliable instrumentation for measuring transient phenomena has become readily available. As a result, many practical system identification problems are currently being solved with transient input/output pairs rather than with sinusoids. For example, Favour (Reference 4) describes a transient calibration technique for accelerometers; this can save substantial time and manpower.

#### References

3. Nielsen, John P., and Baird, Glenn T., *Air Force System for Nondestructive Testing of Pavement*, Symposium on Nondestructive Test and Evaluation of Airport Pavement, U.S. Army Waterways Experiment Station, Vicksburg, Mississippi, May 1976.
4. Favour, J. D., et al., "Transient Waveform Control of Electromagnetic Test Equipment," *Shock and Vibration Bulletin*, Vol. 40, No. 2, 1970.



And numerous other similar examples are available in the literature (References 5, 6, and 7).

Transient loading techniques have been used in pavement research but only to a minor extent. Systems in which a weight is dropped onto the pavement to simulate the deflection of a moving wheel load have been used. Although the deflection measurements may be useful in detecting the onset of pavement problems (failure), they do not reveal which layer of the pavement is weak (Reference 8). Some preliminary work has been done on adapting geophysical seismic techniques to the pavement identification problem. However, seismic techniques have been unsuccessful in pavement evaluation application because seismic identification of soft layers under hard layers is not a well-posed problem and it does not have a unique solution (Reference 9). That is, conventional seismic techniques are theoretically incompatible with real pavement systems.

The basis for the research reported herein is a state-of-the-art paper prepared by CERF in 1975 (Reference 10). This paper suggests the use of impulse loading with measurements in the time domain to record the time-of-arrival of reflected waves at the impact point. However, time-domain measurements of this type are subject to serious error and, thus, this particular approach was rejected. However, a combination of impulse loading and time-domain accelerometer data was considered feasible and was adopted for this research. Furthermore, this approach was considered useful, particularly in

#### References

5. Dorsey, D. M., *System Calibration by Dynamic Response Analysis*, Sandia Laboratories Report SC-DR-69-816, Albuquerque, New Mexico, 1970.
6. Schulz, G. L., *Method of Transfer Function Calculation and Distorted Data Correction*, AFWL-TR-73-300, Air Force Weapons Laboratory, Kirtland Air Force Base, New Mexico, March 1975.
7. Merritt, P. H., *A Method of System Identification With Experimental Investigation of Real Systems*, Ph.D. Dissertation, University of New Mexico, Albuquerque, New Mexico, December 1974.
8. Private Communication with H.A.B. Rao, Bechtel Corporation, 50 Beale Street, San Francisco, California.
9. Mooney, H. M., *Handbook of Engineering Geophysics*, Publication by Bison Instruments, Inc., 5708 West 36th Street, Minneapolis, Minnesota, 1973.
10. Bickle, L. W., *Hopkinson Bar Technique for Nondestructive Pavement Testing*, University of New Mexico, Albuquerque, New Mexico, August 1975.

view of recent developments in the analysis of time-domain data by Discrete Fourier Transform (DFT) techniques (Reference 11).

This effort was not the first to make use of impulse loading in pavement research. A Federal Highway Administration report (Reference 12) lists four impulse loaders which have been or are used in pavement research. (Impulse loaders were used as early as 1960.) However, in all these applications only pavement deflections were measured; i.e., the loader was not used to generate stress waves within the layers of the pavement. In this research an impulse loader was used to generate stress waves; it replaces the vibrator and its support equipment in the CERF NDPT Van. Such a device can be transported by air. This approach also takes full advantage of the data-acquisition and data-reduction schemes previously developed.

The impulse loader used in this study is shown in Figure 2. Fabricated on a surplus bomb dolly, it has two vertically guided drop weights (Figure 3). The center tube contains a 500-pound weight with variable drop heights of 6 to 24 inches. The smaller (side-mounted) tube contains a 50-pound weight with drop heights up to 5 feet. Both weights are raised manually and quick-released to impact on the pavement. This apparatus was fabricated with minimum consideration toward air-transportability. Rather, the device was built to demonstrate the potential of impulse loading, to understand some of the operational problems associated with such a device, and to evaluate the range of input energy required to obtain reasonably good data. However, it is a simple matter to visualize a smaller air-transportable version of this device.

In operation, the weight does not directly impact the pavement, but rather it impacts against an aluminum plate. (Plates of various sizes and materials have been used; e.g., wood and rubber plates have been used to increase the low frequency content of the accelerometer signals.) The accelerometers are epoxied to the pavement at 2-foot intervals (Figure 4). This is the same practice recommended for the CERF NDPT Van (Reference 3).

#### References

11. Stearns, S. D., *Digital Signal Analysis*, Hayden Book Company, 1975.
12. Lytton, R. L., et al., *Pavement Evaluation: Phase I. Pavement Evaluation Equipment*, Report No. FHWA-RD-75-78, Department of Transportation, Federal Highway Administration, March 1975.

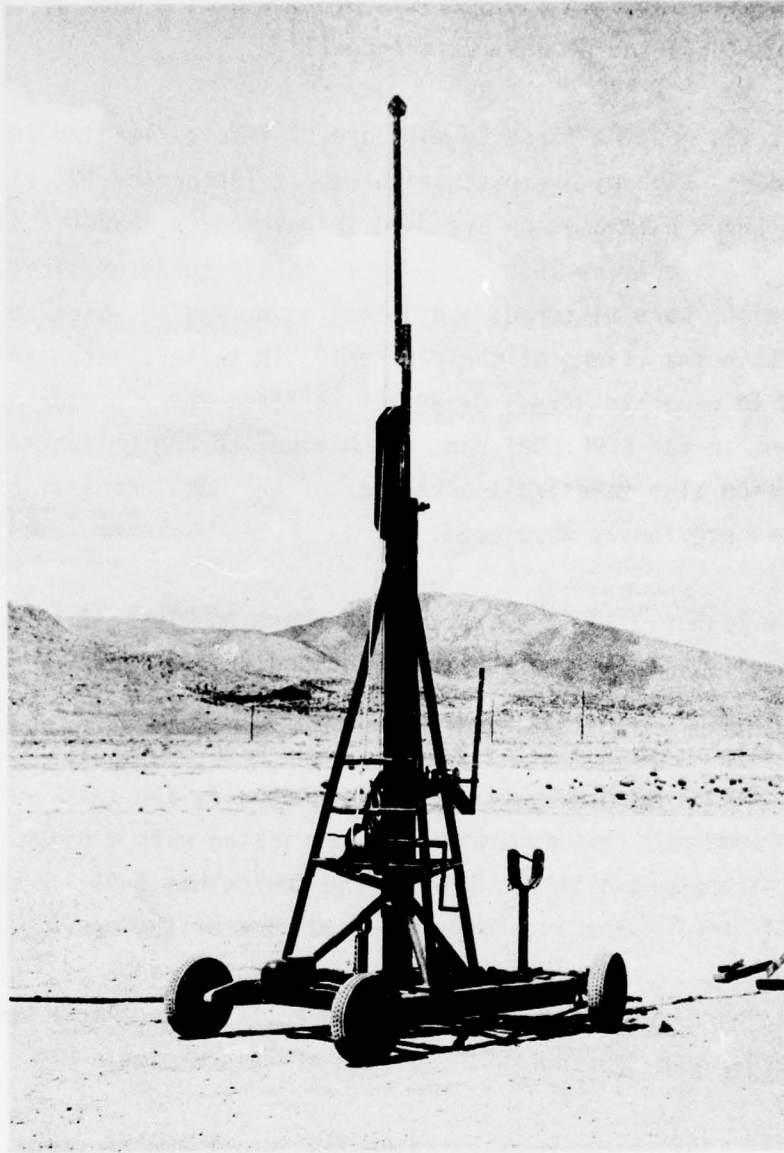


Figure 2. First-Generation Impulse Loader

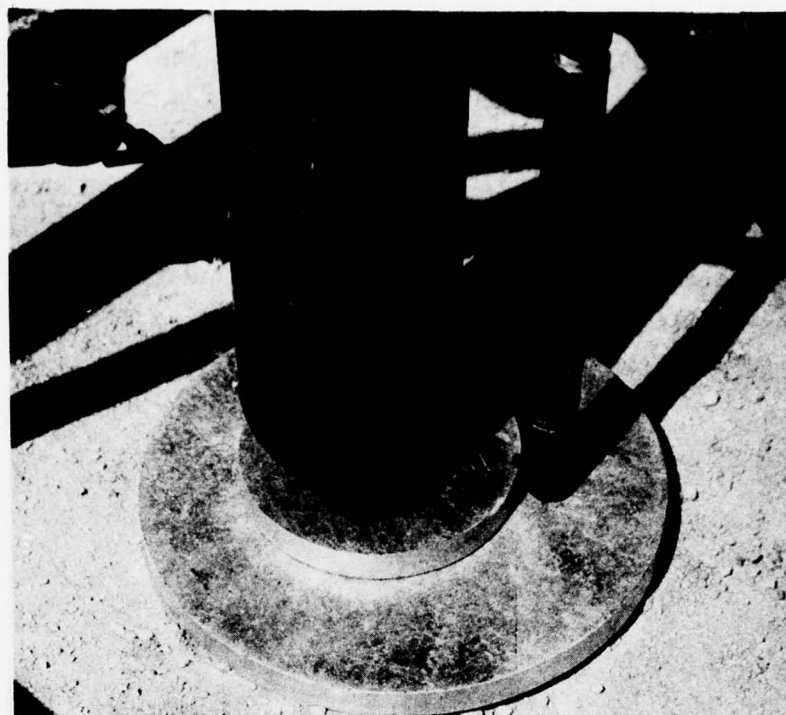


Figure 3. Drop Weights

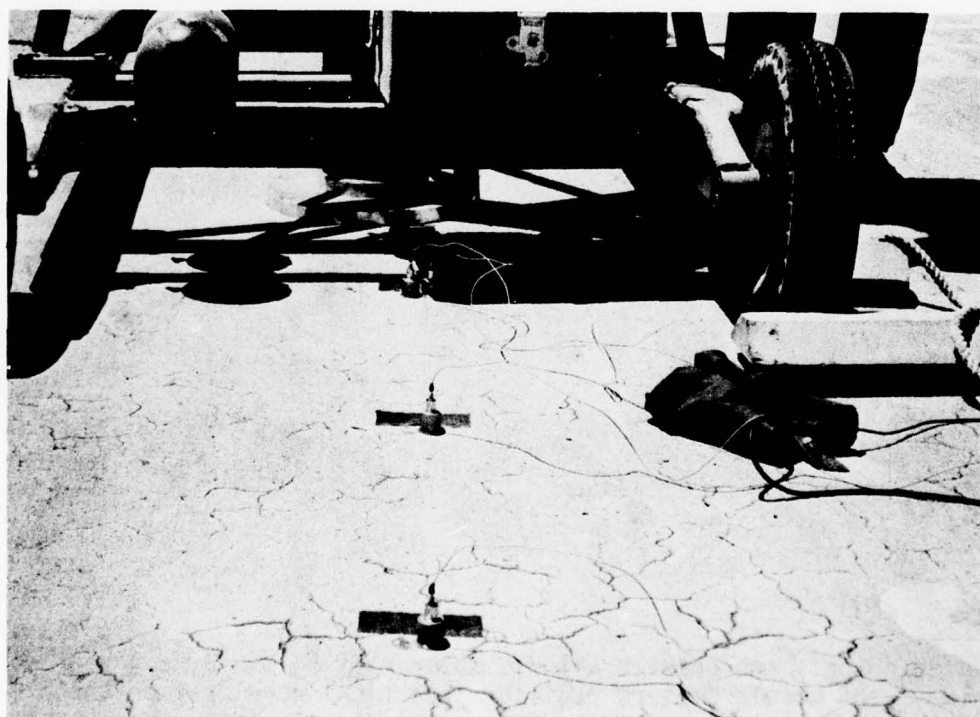


Figure 4. Accelerometer Layout



In general, the best signals were obtained with the 50-pound weight dropped from low points; i.e., the analog time signals (accelerometer outputs) were more reproducible with the lower drop heights.<sup>1</sup> The frequency content of the signals usually exceeded the maximum frequency of interest, viz., 5000 Hz. Although this version of the impulse loader was satisfactory as an evaluation model, further development of smaller models was not undertaken because certain problems with the data acquisition and reduction precludes CERF from positively asserting that an impulse loader can replace the vibratory system. This matter is discussed in Section III.

Footnote

<sup>1</sup>Higher drop heights and heavier weights apparently form a dynamic deflection basin. Thus, the accelerometers register a vertical acceleration which cannot be distinguished from that caused by the outward propagating stress waves, and the real-time data which reflect in-situ material properties are distorted.

### SECTION III ACCELEROMETER

To assure quality in the ultimate data, the acceleration measurements must be highly accurate over the frequency range of interest. The requirements for this measurement include the following:

- (1) A wide operating-temperature range
- (2) A wide g-range with moderately high output on low g-ranges
- (3) A broad frequency passband with minimal phase shift within the required band
- (4) Good linearity (Nonlinear transducers are frequency creative; they yield frequency components at their output which are not part of the input signal.)

Conventional piezoresistive accelerometers have extremely good low frequency capabilities. However, to provide reasonable sensitivity at low g-levels, the natural frequency of the transducer must be so low that the high frequency capabilities are not adequate.

Piezoelectric accelerometers have low frequency limitations, but they offer high sensitivities which provide adequate signal levels during low-peak g-tests. They also provide very good high frequency capabilities because of their inherent high natural frequency.

The transducer selected was the Endevco Model 225-1 accelerometer. These devices accept up to 500 g with no damage at 500 g with piezoelectric, shear mode design. They provide nominal outputs of 5 mV/g with an amplitude linearity specification of less than 1 percent increase over the 500-g range. Mounted resonant frequency is 40 kHz undamped with a passband within  $\pm 5$  percent over the 4-to-8000-Hz range. Transverse sensitivity for these devices is 3 percent and the operating-temperature range is  $-50^{\circ}$  to  $125^{\circ}\text{C}$  with a sensitivity deviation tolerance of  $\pm 2$  percent over this range.

## SECTION IV

### FIELD TESTS

#### TEST PROCEDURES

To perform an evaluation of the impulse loader, the test equipment was taken to the runways for which wave propagation data had been obtained with the CERF NDPT Van. Accordingly, tests were performed at Williams, Luke, and Cannon Air Force Bases. The necessary data-acquisition equipment, which included signal conditioners, a recorder, and control and test components, was assembled in the CEEDO inertial profilometer van; the impulse loader was transported by trailer.

The apparatus was set up on the runways at exactly the same locations as those used in earlier surveys with the CERF NDPT Van. The accelerometers were epoxied to the pavement, and following calibration of the electronic gear the pavement was impacted by the impulse loader. The test procedure consisted of varying the drop height and the plate size and repeating drops under the same conditions so as to evaluate reproducibility of results. The pavement at Williams Air Force Base is asphaltic concrete; Luke has Portland cement concrete pavements. However, some of the accelerometer couplers malfunctioned at Luke and, hence, the pavements at Cannon Air Force Base were tested to obtain the data on concrete pavements.

#### DATA REDUCTION

The first step in the data reduction consisted of obtaining unscaled O-graphs of the analog tape. These plots were used to obtain the time of impact and to check for bandedge. The analog tape was then digitized (20,000 samples per second) and unscaled plots of each impact were obtained for review. Figure 5 shows a typical time history of an impact. The first spike represents the initial hit; the following spikes represent the successive hits due to restitution. A drift is clearly apparent on this plot. Next, individual time histories were obtained; e.g., the time history of the first impact. Such a

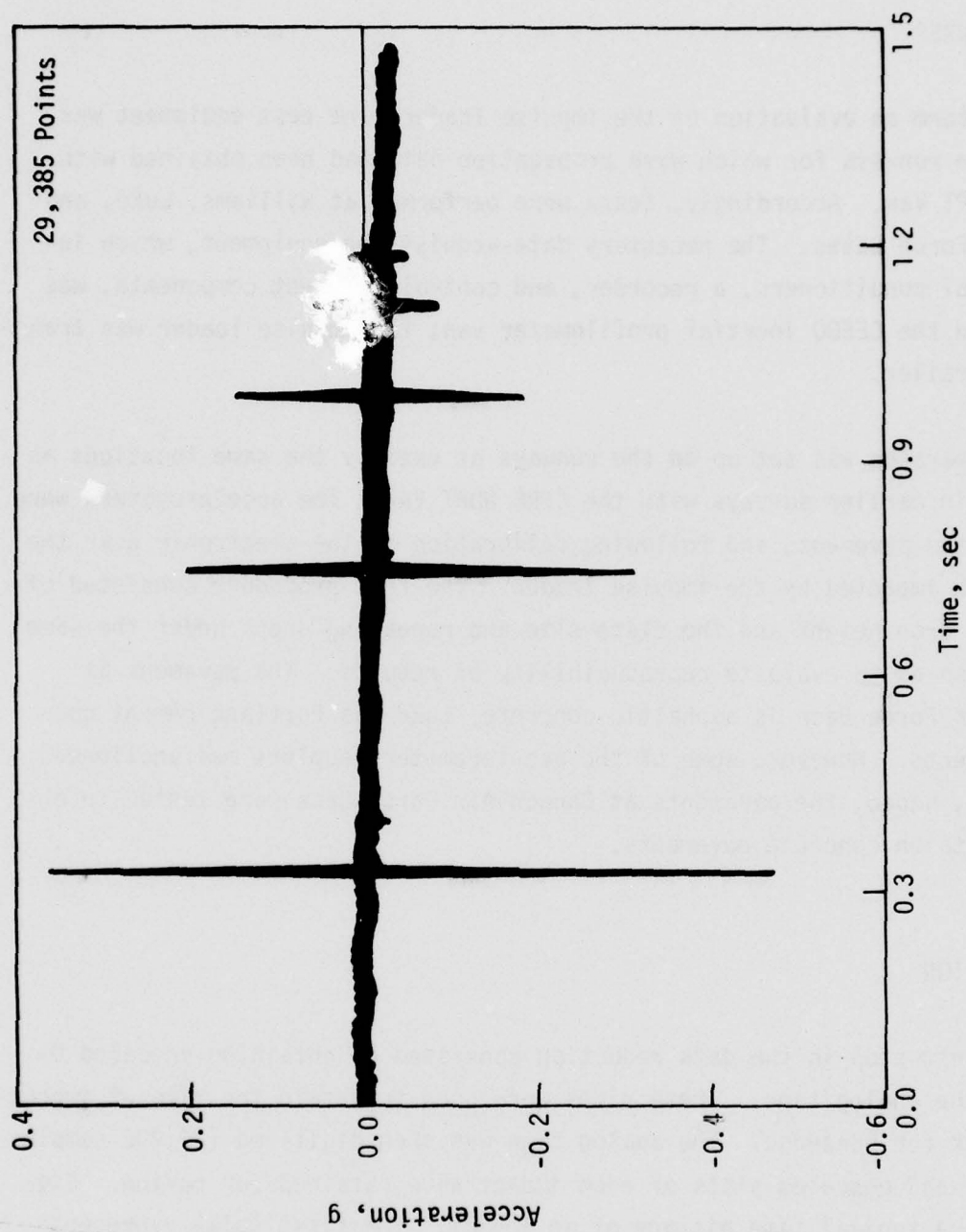


Figure 5. Typical Accelerometer Time Trace from Multiple Impacts



plot is shown in Figure 6. The time history was then *cleaned up* as shown in Figure 7 by zeroing out the noise (on the front end of the signal) and the drift. These corrected time histories for each accelerometer were then used in a DFT to obtain the desired phase angle/frequency plots.

#### PHASE ANGLE/FREQUENCY PLOTS

The objective of the field tests was to compare the phase angle/frequency plots obtained from impulse loading with those obtained from vibratory testing (CERF NDPT Van). Figure 8 shows plots for an asphaltic concrete pavement at Williams Air Force Base; Figure 9 shows a similar plot for a Portland cement concrete pavement at Cannon Air Force Base. These plots are typical of the many developed as part of this study. In general, the comparison is favorable. The impulse data have a general trend of being incoherent at high frequencies. Additionally, the comparison is affected by the number of points taken into the DFT. For example, Figure 9 shows a 512-point transform; Figure 8a shows a 2048-point transform; and Figure 8b shows a 4096-point transform. The increase in detail is apparent as the number of points in the DFT increases.

The most appropriate number of points to use in the analysis of a pavement is a subject that requires further investigation. There are, however, differences in the dispersion curves that result from the two test methods (impulse versus vibratory testing) as shown in Figure 10. For this particular pavement, impulse testing revealed a higher surface phase velocity (7600 ft/sec) and a higher subgrade shear velocity (2900 ft/sec) than those obtained by vibratory testing. However, CERF's experience indicates that this trend toward higher phase velocities with impulse testing is not always the case, and indeed no real trends either way could be detected. CERF's position is that impulse loading can replace vibratory testing, and thus an air-transportable NDPT device can be built. CERF used off-the-shelf equipment to perform these field tests. As such, the equipment has been pushed to its limits to achieve good data. Furthermore, certain restrictions placed on CERF by the AFWL analog-to-digital conversion equipment have limited the quality of the phase angle/frequency plots.

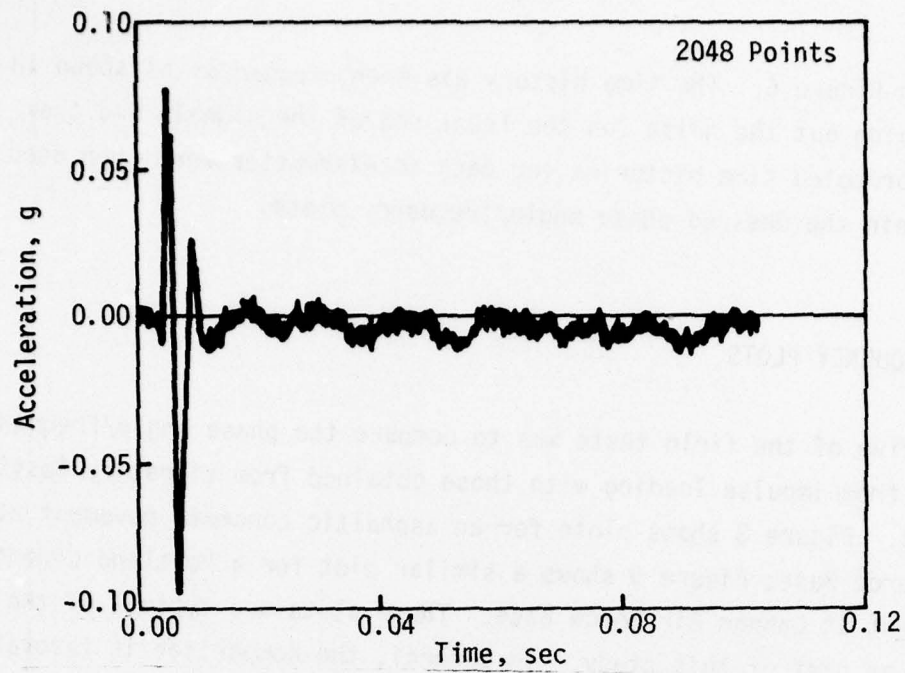


Figure 6. Typical Accelerometer Time Trace from Single Impact

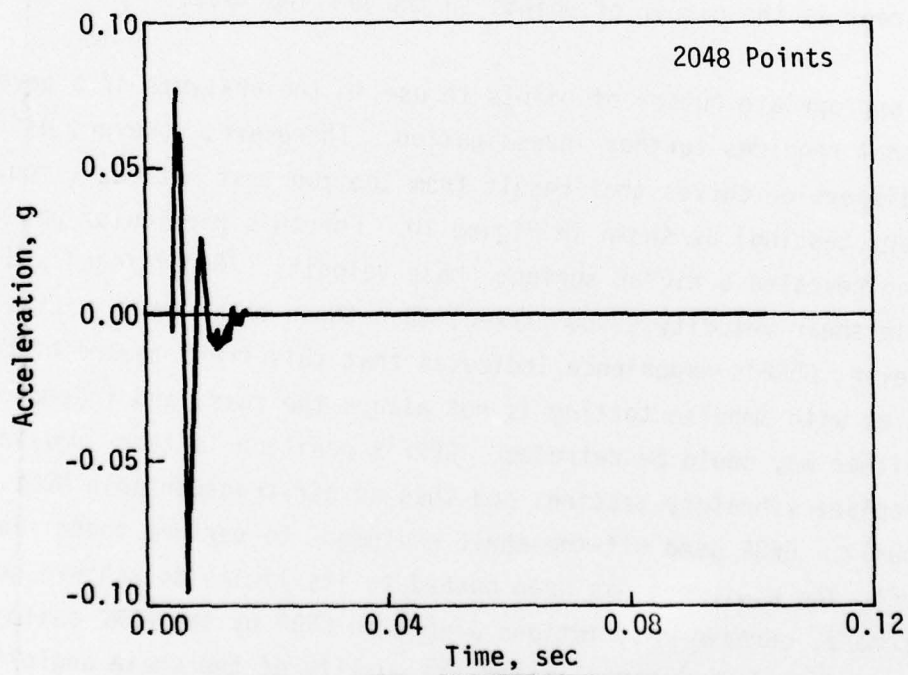
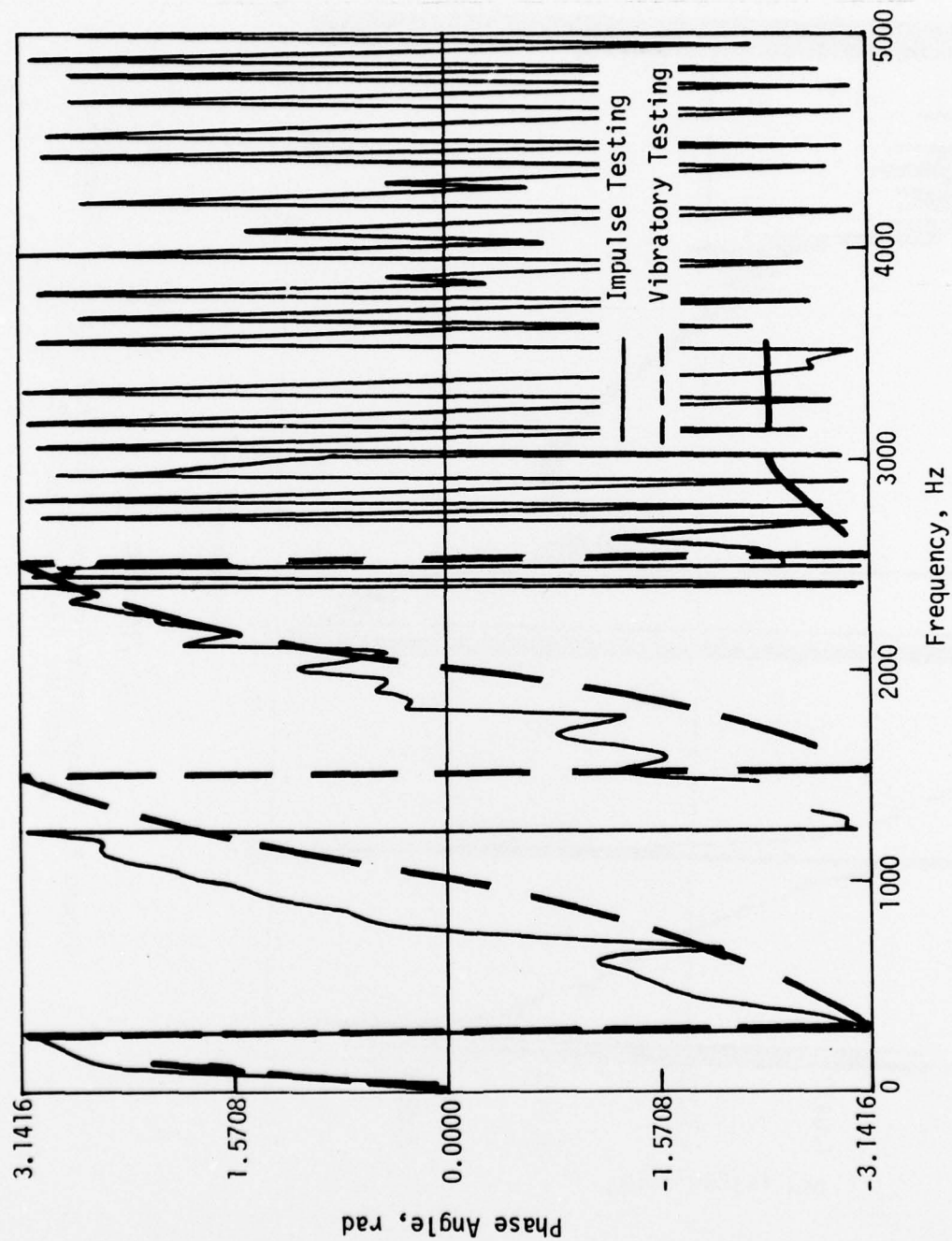


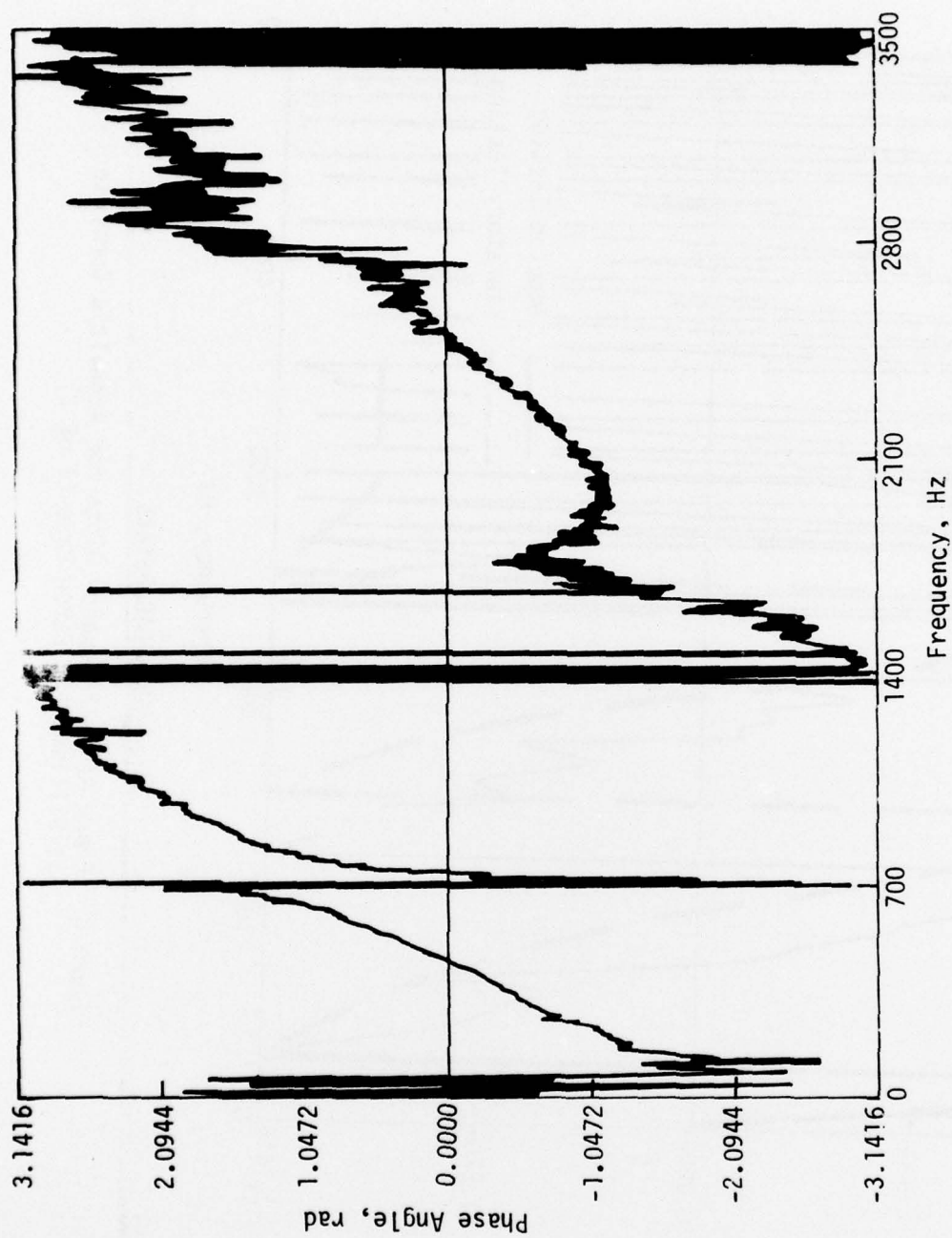
Figure 7. Adjusted Accelerometer Time Trace



(a) 512/2040 Points

Figure 8. Phase Angle/Frequency Plots for Asphaltic Concrete at Williams Air Force Base (1 of 2)





(b) 716/4096 Points

Figure 8. Phase Angle/Frequency Plots for Asphaltic Concrete at Williams Air Force Base (2 of 2)

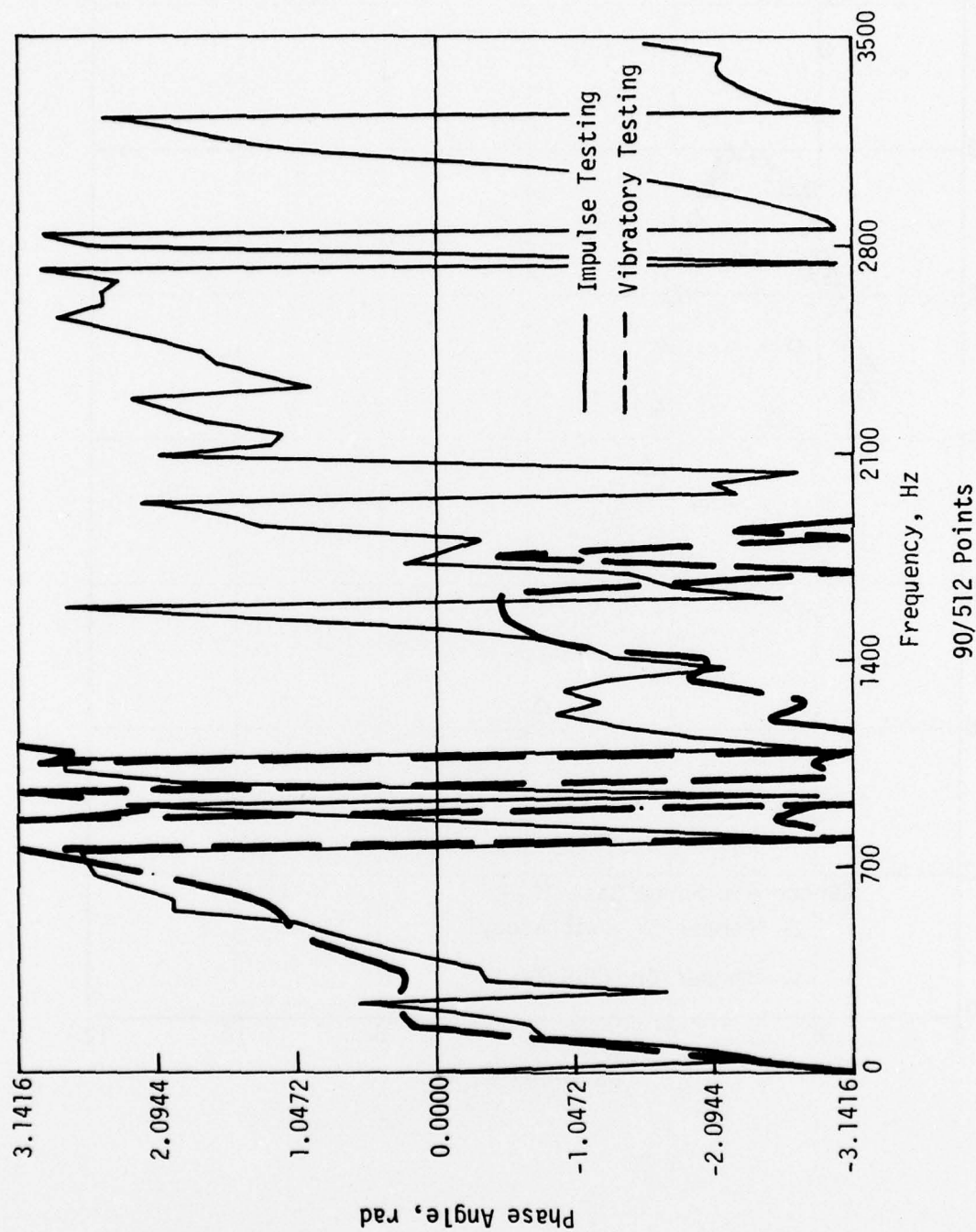


Figure 9. Phase Angle/Frequency Plot for Portland Cement Concrete at Cannon Air Force Base

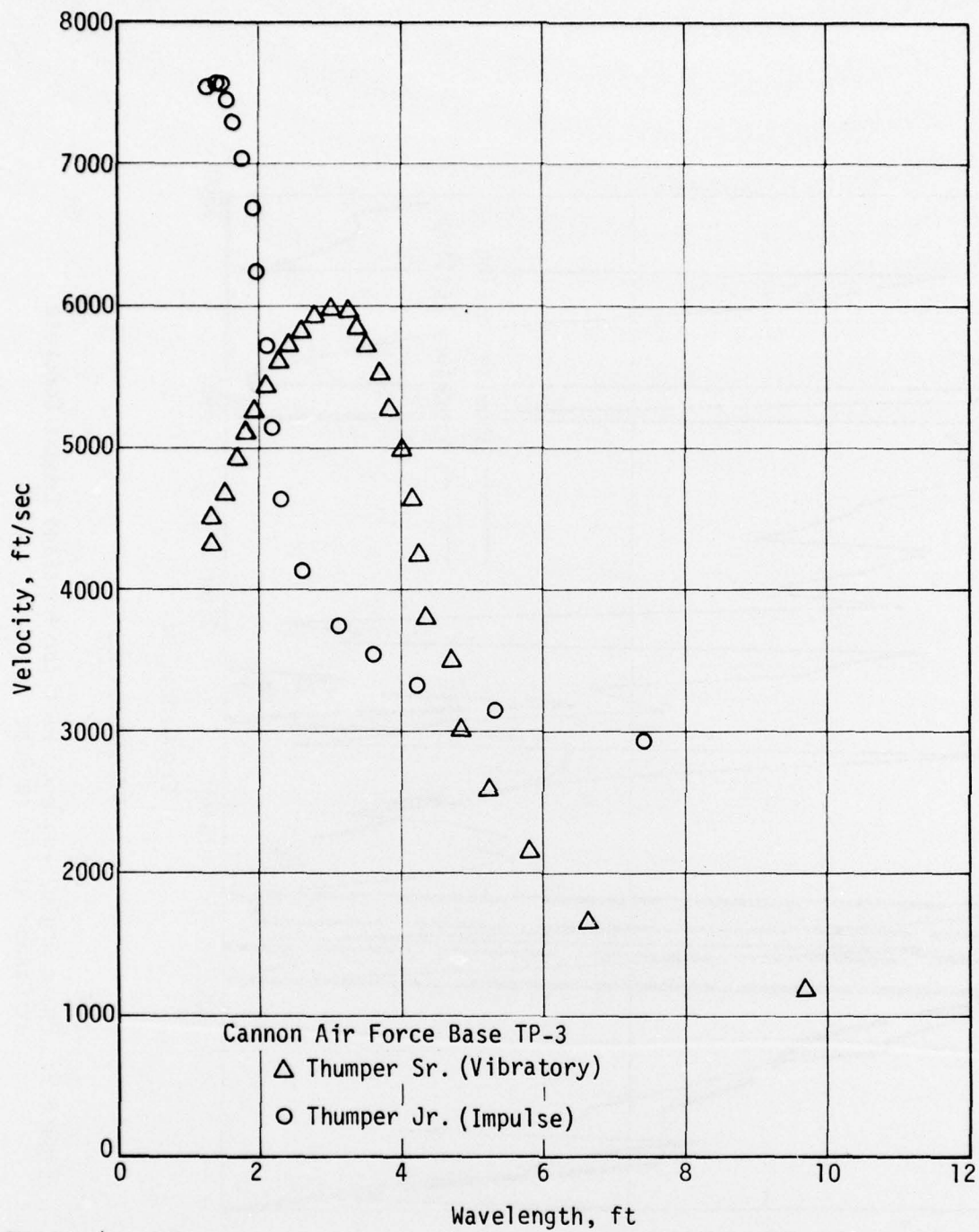


Figure 10. Dispersion Curves from Impulse and Vibratory Testing



In summary, CERF is of the opinion that it has reached the limits of its resources in the process of evaluating the impulse loader. CERF feels that there is an 85-percent chance that the concept of an impulse loader for NDPT can be developed to meet the needs of the Air Force. Accordingly, the research plan presented in Section V is recommended in order to fully develop the impulse loader.

## SECTION V

### RECOMMENDED RESEARCH

#### OBJECTIVE

The research described in this section outlines an advanced development effort to build and validate a system to perform nondestructive load evaluations of airfield pavements with air-transportable test equipment. In addition to the equipment development, the effort includes the training of CEEDO personnel, the preparation of a user's manual, and the transfer of the technology required to interpret the data and perform load evaluation predictions.

#### SCOPE

The work accomplished under the present effort has demonstrated the feasibility of using an impulse loader to provide data concerning the in-situ elastic properties of paving materials. The research outlined in this section describes an effort to build an air-transportable NDPT device. Specifically, the program contains six distinct goals as follows:

- (1) Acquisition of the necessary electronic equipment, cargo van, and other support equipment, and installation of the equipment in the van
- (2) Fabrication of a second-generation impulse loader
- (3) Field tests on a wide variety of pavements (These should be the same pavements tested as part of the validation program for the present vibratory system.)
- (4) Modification of the system as required (based on the experience gained in performing the above field tests), permanent installation of the equipment in the cargo van, and fabrication of the final working impulse loader
- (5) Field test of impulse loader and finalization of operational and data-reduction procedures
- (6) Preparation of a user's manual and training of CEEDO personnel on equipment operation, data reduction, and interpretation techniques

## TECHNICAL REQUIREMENTS

In pursuing the above goals the following tasks are required:

- (1) The electronic acquisition and reduction equipment required for the air-transportable impulse testing system shall be purchased and installed in a cargo van (also purchased). As a minimum this equipment shall consist of a digital-processing oscilloscope, a central control console consisting of a keyboard and a cathode ray display tube, a programmable control module, and a copier. This system shall be capable of digitizing eight channels of data, processing paired channels through a DFT, and reducing the resulting transform to a dispersion curve. The support equipment shall consist of an air conditioner, an electric energy generator, and other necessary support items. The cargo van shall have a minimum 3/4-ton chassis with a modified suspension to protect the electronic equipment from road shock.
- (2) Based on the experience documented in Sections II through IV, a second-generation impulse loader shall be built. This loader may operate either manually or mechanically. Consideration should be given to making the loader transportable within the cargo van.
- (3) Field tests shall be performed at Air Force bases where the NDPT vibrator has been used to perform load evaluation studies so as to provide validation data for the impulse system.
- (4) Based on the experience gained in performing the above tasks, the data acquisition and load impulse generator shall be modified and improved as required. The equipment shall be permanently mounted in the van in a manner that will minimize damage from road shock. The test equipment shall be installed so that a single operator can control the test, display the data, and perform operational functions as required via a central control console.
- (5) The final working system shall be evaluated at several test sites to validate the system and finalize operational and data-reduction procedures.



- (6) A user's manual shall be prepared. CEEDO personnel shall be trained on operation of the equipment and data-reduction techniques.

## EQUIPMENT

The digital-processing equipment required to provide a data-acquisition system for an impulse-type NDPT device should contain the following:

- (1) Eight channels of simultaneous data acquisition
- (2) 512 words by 10 bits per data channel of storage
- (3) A dedicated processor to remotely control data acquisition
- (4) A processor to control the data acquisition as well as to perform all necessary data analyses
- (5) A terminal to provide user interaction with the system as well as alphanumerical and graphic display
- (6) A hardcopy printer to provide a permanent visual record of the information output by the system
- (7) A mass storage device capable of inputting and outputting data and programs to the system as well as being an economical medium for off-line storage of information for later retrieval
- (8) A complete analytical software package to control the above equipment and perform the functions described

The Tektronix WP-1221 Signal Processing System is recommended. It includes the following equipment:

- 7704A Oscilloscope (two)
- P7001 Processor (two)
- 7A26 Amplifier Plug-In (four)
- 7B80 Time Base Plug-In (two)
- 7B85 Time Base Plug-In (two)
- CP4165 Controller (one)
- R4010-1D Terminal (one)
- CP112 Dual Flexible Disk Memory (one)
- 021-0117-01 Interface (one)
- 021-0116-02 Interface (one)

4610 Hardcopy Unit (one)  
016-0541-00 4610 Cradle mount (one)  
040-0683-01 DPO Cradle mount (two)  
CP85871 Tek SPS Basic Monitor/Interpreter (one)  
CP71171 Op 5 Tek SPS Basic DOP Driver (one)  
CP91171 Op 5 Tek SPS Basic Signal Processor (one)  
CP91271 Op 5 Tek SPS Basic Graphics (one)  
437-0177-01 Cabinet (three)  
Manuals (one set)

This system provides up to eight channels of data acquisition at 512 words by 10 bits. The CP4165 controls the data acquisition and analyses with Tek SPS Basic Software. Operator interface to the system is through the R4010-1D Terminal. Alphanumeric and graphic information can also be displayed on the R4010-1D and this display can be permanently recorded by the 4610 Hardcopy Unit. Data and programs can be stored and recalled by the CP112 Flexible Disk Memory. Finally, this system can be installed in a van which is air-transportable in a C-130 aircraft.

A van of the type shown in Figure 11 is recommended for housing the data-acquisition system. Known in the trade as *Hi-Cube* vans, this configuration is required to meet the height requirements for the data-acquisition system installation (mounted in three racks). Because of the demand for vehicles of this type it will be necessary to solicit bids from several manufacturers in order to obtain delivery in a reasonable time. At this time (September 1977) the delivery period for a Hi-Cube van is 3 to 4 months. If a particular vehicle manufacturer is desired, CEEDO should inform CERF. An advantage of a Hi-Cube van is that CERF may be able to design an impulse loader which can be transported in the van, rather than on a trailer.

Support equipment, such as a generator, air conditioner, radios, flood-lights, etc. have not been identified as to manufacturer and model number. These items should be secured on an individual basis and installed in the van as the project develops.

A = 259 inches      E = 95 inches  
B = 167 inches      F = 84 inches  
C = 74 inches      G = 67 inches  
D = 91 inches      H = 163 inches

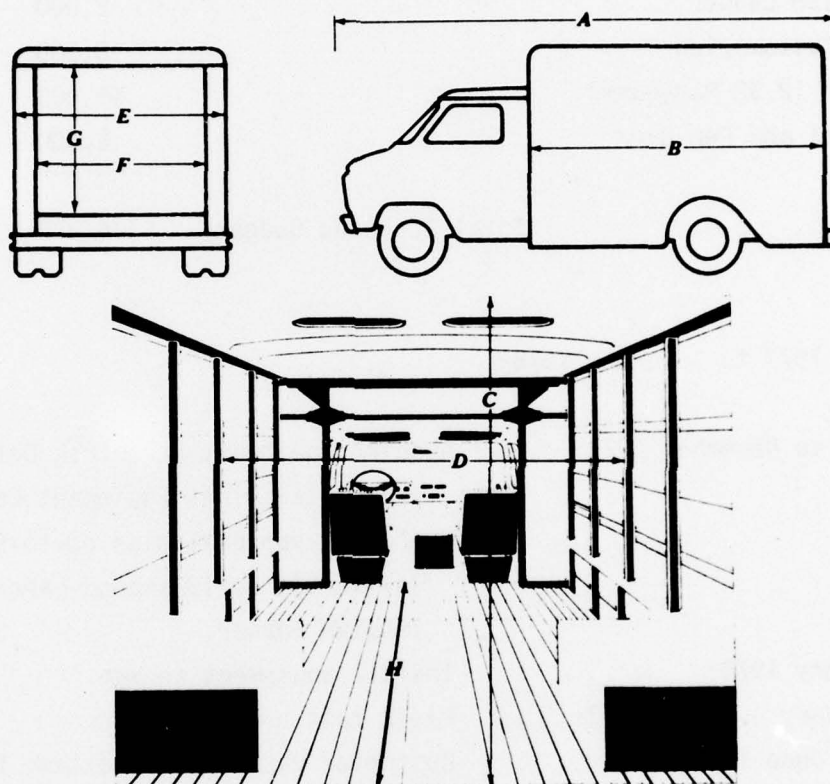


Figure 11. Recommended Van Body



## BUDGET

|                        |                                 |                 |
|------------------------|---------------------------------|-----------------|
| I.                     | Electronics, Data-Processing    |                 |
|                        | Tektronix                       | \$ 58,900 (GSA) |
|                        | Digital-Processing Oscilloscope |                 |
|                        | Cathode Ray Tube and Keyboard   |                 |
|                        | Copier                          |                 |
|                        | Central Control                 |                 |
|                        | Generator, 6-kW                 | 2,500           |
| II.                    | Cargo Van, 3/4-Ton              | 10,000          |
| III.                   | Impulse Loader                  | 2,000           |
| IV.                    | Van Customizing                 | 5,000           |
| V.                     | Labor (2.32 Manyears)           | 90,000          |
| VI.                    | Travel and Per Diem             | 6,000           |
|                        |                                 | <hr/>           |
| Total Proposed Budget: |                                 | \$174,400       |

## SCHEDULE (July 1977 to November 1978)

|      |                            |  |
|------|----------------------------|--|
| I.   | July to December 1977:     | Acquire equipment [requires Defense Industrial Plant Equipment Control (DIPEC) approval plus 60-to-90-day delivery]; build second-generation impulse loader. |
| II.  | January 1978:              | Install equipment in van.  |
| III. | February - April 1978:     | Field test.  |
| IV.  | May, June 1978:            | Customize van; build and test final impulse loader.  |
| V.   | July, August 1978:         | Evaluate final design.   |
| VI.  | September - November 1978: | Train CEEDO crews; prepare user's manual.  |

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